International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 9, Issue 2, Apr 2019, 123-136

THE FAILURE MODE EFFECTS ANALYSIS TO PREVENT DELAYS FOR DEVELOPMENT PROJECTS IN AEROSPACE INDUSTRY - A CASE STUDY

JAMES JOSEPH[1], SRIRAM. K. V[2], ASISH OOMMEN MATHEW[3] & ARJUN KANOOR[4]

[1,2]*Associate Professor, Department of Humanities and Management, Manipal Institute of Technology, Manipal Academy of Higher Education, Karnataka, India*

[3]*Assistant Professor, Department of Humanities and Management, Manipal Institute of Technology, Manipal Academy of Higher Education, Karnataka, India*

[4]*Post Graduate Student, Department of Humanities and Management, Manipal Institute of Technology, Manipal Academy of Higher Education, Karnataka, India*

ABSTRACT

Delays in development projects are prevalent in the aerospace industry. The AS9102 standard suggests that Failure Mode and Effects Analysis is an effective tool in the identification and mitigation of risks and failures. Process FMEA helps to identify failures in a production system from each work-centre. Special emphasis was placed on the identification of factors that caused serious delays or that prevented the production system from performing at levels that enabled the achievement of the customer delivery schedule. The creation of a risk matrix of the parts and the work-centres in the project yielded the individual risk scores for the individual parts being manufactured. Additional criticality was assigned to parts that experienced multiple failures, this resulted in identification of the critical work-centres, the number of failures per work-centre, the critical parts and the number of failed individual parts. This gave the project managers a comprehensive view of the risk involved in the manufacturing of the parts in the project. Despite the initial delays in the project, the customer delivery schedule of a ship-set every three weeks was achieved within 5 ship-sets. A strategy for a planned resource dilution was identified by simulating multiple levels of dilution so as to not result in delays.

KEYWORDS: Process Failure Mode and Effects Analysis (PFMEA), First Article Inspection (FAI), Semi-Finished Goods (SFG), Process Repeatability, Weighted Risk Priority Number (RPN), Final Panel & Risk Score

Received: Dec 28, 2018; **Accepted:** Jan 18, 2019; **Published:** Feb 13, 2019; **Paper Id.:** IJMPERDAPR201912

A CASE STUDY

1. INTRODUCTION

The company under investigation is a subsidiary of a large manufacturing conglomerate located in Benguluru, India. The factory is set up on 16 acres of land and employs over 500 skilled engineers and operators. The company was established in 1989 as matrix materials and commenced commercial operations in 1993. They specialise in the manufacturing of aerospace composites and industrial composites. The plant has 4 clean rooms with a total of 2000 sq. m of floor space, 6 autoclaves, 2 ovens, 3 5-axis CNCs, 2 3-axis CNCs.

The plant is involved in making the interior panels for the P8 aircraft. A shipset contains 51unique assemblies consisting of a total of 136 panels. The parts manufactured are sandwiches of Aramid (Kevlar) honeycomb core between 1 or 2 layers of phenolic glass pre-impregnated epoxy sheets. Each part is inspected after

every major stage. Samples are also created per cure cycle for destructive and non-destructive testing. All the parts are also inspected under a laser tracker. This size and complexity in this project have resulted in major delays in the clearing of FAI. The process defined by the First Article Inspection (FAI) should achieve repeatability for production handover. A delay in achieving repeatability post FAI results in delayed customer deliveries and mounting costs as parts are scrapped repeatedly. Process repeatability can be achieved by analysing the cause of failure of parts and the occurrence rate of said failure. If a part failed to clear the any of the stage inspections and would result in the scrapping of the part, the part has to be re-issued and all the operations carried out in sequence to complete the delivery of the ship-set. This process resulted in excessive time taken between a part being scrapped and then eventually being accepted after required rework or re-issuance of said part. Certain work-centres suffered from a multiple failure of particular parts that resulted in some parts being re-issued and scrapped multiple times before a solution was identified, skill levels of operators was an area of concern for failures at certain stages. This resulted in mounting costs and delayed schedules.

The objective of the study is to identify the critical operations, the identification of the critical parts in a ship-set, creation of a system that reduces the time taken between a part being scrapped from the system, the re-issuance of a new work order and part and the eventual completion of the critical operation and subsequent operations to yield a compliant part. This will help in identifying all the critical parts and operations, the creation of a system of Semi-Finished Goods (SFG) storage and the reduction in overall cycle time for a ship-set.

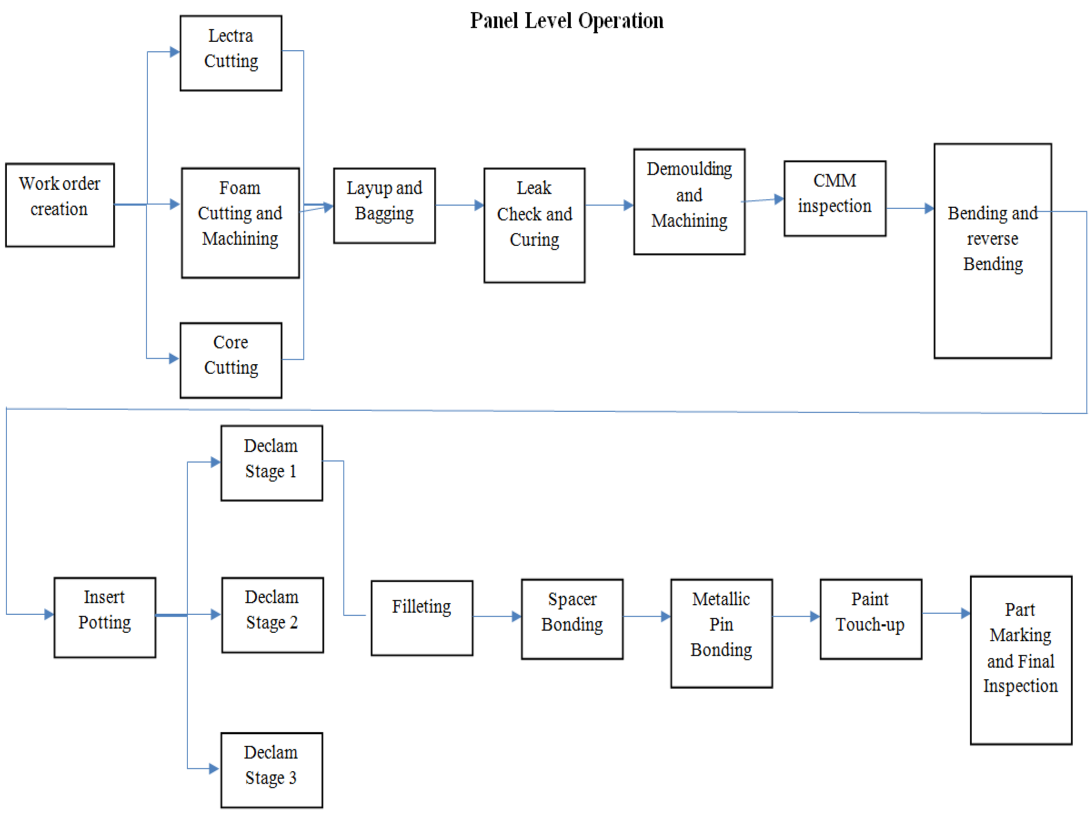

Figure 0.1: Panel Manufacturing Process Flow

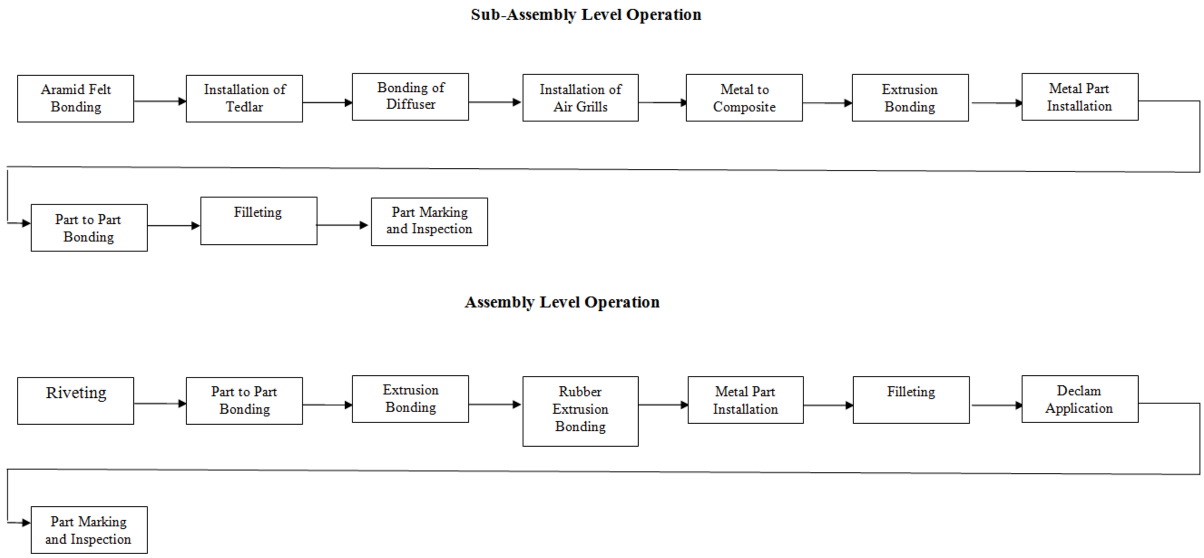

Figure 1.2: Sub-Assembly and Assemble Manufacturing Process Flow

2. OBJECTIVES

- To perform PFMEA and identify factors causing delays
- To identify the critical operations and critical assemblies by the medium of a matrix structure of parts and the risks associated in manufacturing of the parts
- To identify the various factors affecting the production of parts in stage one of production and to find ideal resource dilution in layup work-centre without causing delays.

3. LITERATURE REVIEW

The First Article Inspection process is defined as a complete planned and independent inspection, verification and documentation of a prescribed production process to have produced an item conforming to the Engineering Design, Digital Product Definition (DPD), engineering specifications, purchase order and/or other applicable documents and specifications. (Baker & Mooney 2014)

Robinson (1990) states that the quality management systems should act as a preventive tool. Risk based thinking and risk management processes are to be used as preventive tools to bolster the quality management systems. In clause 8.1.1 it states that risk is expressed in terms of likelihood of occurrence and the severity of occurrence of any risk that is likely to be associated with the operational processes for the products and services delivered in the facility. These actions include the understanding of the risks and their impacts on the production process and the undertaking of decisions and actions to manage the identified risks.

Carbone and Tippett (2004) observe that in a project the identification and the mitigation of risks is essential to the successful completion of the project. They state that organisations should place value on the identification of failures and shortcomings in this vain the authors suggest the use of Failure Modes and Effects Analysis (FMEA) as a suitable tool in the analysis of the system and the subsequent identification, categorisation and the mitigation of risks.

Eizakshiri et al. (2015) in their study state that in cases of delays in projects often the blame is pinned on the project plan or in the implementation of the plan. Instead the authors argue that the system itself must not be exempt from being the reason. They also state that project delay should be considered in the planning phases and that a system to mitigate delays in the plan based on past experiences should be put in place. Delays should be considered with all the parties who contribute to the delay in the project and not just on flawed planning or execution. Plans should be created with a future focus and with the learnings of the past projects.

Bahrami et al. (2012) argue that FMEA is a simple, and a systematic approach in identifying failures and errors in a project, process or system. They say that it helps in the correction of errors in a project and is also plays a key role in continuous improvement in the project. These continuous improvement processes help in the reduction of labour, cost and time to completion of a project. FMEA helps in comparing linked processes by their Risk Priority Number (RPN) values and can further help in identification of faults and aid in their corrects. These processes help in the proper utilisation of the project's resources.

The reliability and the quality of the manufacturing process is crucial to the products manufactured. Process FMEA is a very powerful tool in identifying risks in the production process that can yield unreliable products stemming from unreliable or faulty production processes. FMEA helps in the prioritisation of the various faults in the production system and provides a systematic flow for the correction of failures and the results of which too are documented. This yields constant positive change and also helps in the reduction of waste in a manufacturing process by the reduction of faulty parts, tooling problems etc. Properly conducted FMEA also helps in future scope for improvements in the production process. (Waghmare et al., 2014)

Lipol & Haq (2011) Risk state that in the current fast paced world of ever shortening product cycle time, it is vital to achieve fast ramping up of production. Conventional methods of risk analysis and continues improvement are not effective during the product development stage. They say that the challenge is in finding a good reliable and simple process to aid in risk identification and mitigation in the early stages of production and for this FMEA is an ideal solution. This they say is due to its simplicity and reliability that it helps in identifying early stage failures

3.1. First Article Inspection (FAI)

First article inspection is a complete and independent process that involves a documented inspection and verification of the production process used to manufacture items in conformance with the engineering drawings, DPD, engineering specification, purchase order etc. The purpose of conducting an FAI process is that the manufacturer is capable of understanding and realising the requirements of the customer, to show the production process required to achieve a conforming product right at the start of the production of the customer's order. Fai process helps in identifying potential failures in the manufacturing process that can yield in non-conforming products, to ensure utmost flight safety.

During the period of the FAI process, a special quality inspection team from the customer is stationed at the manufacturing plant to oversee the entire FAI process. The FAI team inspects the parts manufactured, the production process, the quality control and product inspection process, the product storage process and all intermediate processes that are connected with the production of a conforming product. The FAI team also goes through all the process documents and Standards and Procedures to ensure that all documents meet the required standard for information communicability and its ease in understanding. The FAI team also defines the permitted rework operations and the limitations to rework.

On production of a conforming part as per a prescribed production process, the process to manufacture a part is locked down by the customer to ensure that all subsequent parts that are manufactured follow the exact same procedure to ensure the highest probability of a conforming product. Any subsequent changes to the production process resulting from a change in machinery or continuous improvement processes are raised as a delta-FAI with the customer for approval.

The FAI process helps in ensuring minimal variance between parts and thus improving flight safety. It also helps in identifying inconsistencies at certain points in the production process. The FAI process also familiarises the customer with the manufacturing process and other amenities available at the plant, to enable the customer in selecting suppliers for future projects based on the amenities and the skill identified at the plant. It also ensures that good engineering practices are carried out in the plant.

3.2. Process Failure Mode and Effects Analysis (PFMEA)

PFMEA is a methodical approach to identifying the risks involved a production procedure during the developmental stages of the process. FMEA was first developed in the 1960s by NASA for use on their programs such as the Apollo and Voyager missions. The Society of Automotive Engineers (SAE) first adopted FMEA in 1967. It helps to identify potential points of failure and short comings in the production system from a work-centre view. PFMEA is conducted by the engineers and senior operators

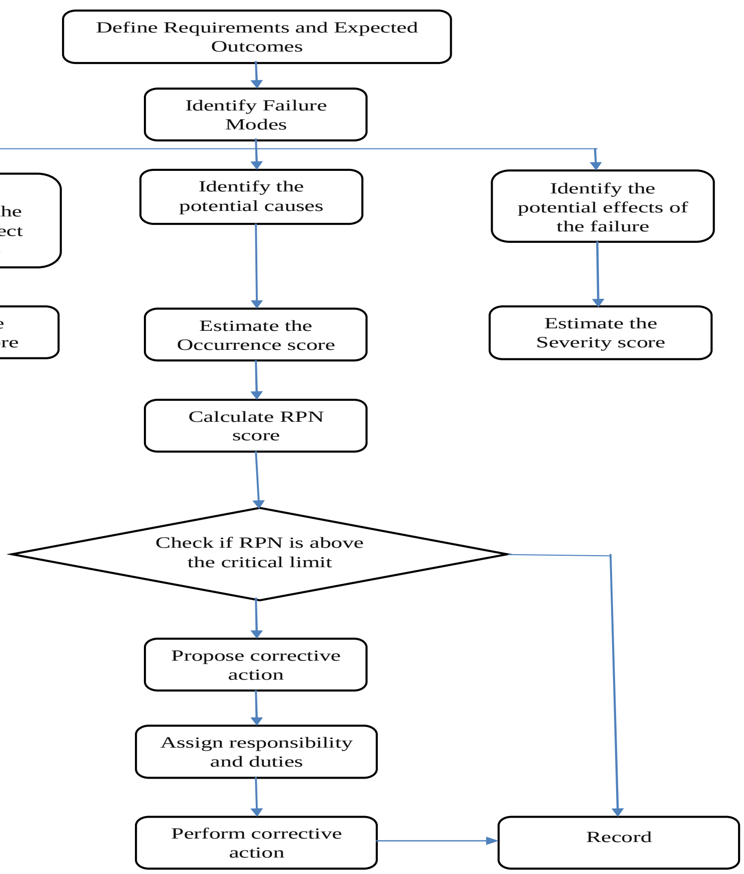

Figure 2.2: PFMEA Process Flow

Detection, the occurrence and severity of a potential failure per work-centre are ranked on a scale from 1-10 with 1 being the lowest rank and 10 being the highest.

The tables below for Occurrence, Detection and Criticality were chosen to provide a common ground for future projects in the facility. This gives a common ground for PFMEA analysis and can even facilitate cross project, project risk calculation and comparison.

Occurrence

Table 0.1: Occurrence Table

Likelihood of Occurrence	Criteria: Possible Failure Rates/Probability of Failure	Rating
Extremely High	Failure rate of less than 5 FPMH/Probability of Failure During Mission <0.2	10
Very High	Failure rate of less than 2 FPMH/Probability of Failure During Mission <0.1	9
High	Failure rate of less than 1 FPMH/Probability of Failure During Mission <0.05	8
Moderately High	Failure rate of less than 200 FIT/Probability of Failure During Mission <0.01	7
Moderate	Failure rate of less than 100 FIT/Probability of Failure During Mission <0.005	6
Moderately Low	Failure rate of less than 20 FIT/Probability of Failure During Mission <0.001	5
Low	Failure rate of less than 10 FIT/Probability of Failure During Mission <0.0005	4
Very Low	Failure rate of less than 2 FIT/Probability of Failure During Mission <0.0001	3
Extremely Low	Failure rate of less than 1 FIT/Probability of Failure During Mission <0.00005	2
Remote	Failure rate of less than 0.2 FIT/Probability of Failure During Mission <0.00001	1

(Standard for Performing a Failure Mode and Effects Analysis (FMEA) and Establishing a Critical Items List (CIL)

Detection

Table 0.2: Detection Table

Detection Criteria	Likelihood of Detection by Process Design or Controls	Ranking
None	There is no Detection of the Failure Mode or its subsequent Failure Effect (not detected by manufacturer or customer and could result in complete failure)	10
Very Remote	There is a very remote probability the Design will detect the Failure Mode or its subsequent Failure Effect (detected when part malfunctions)	9
Remote	There is a remote probability the Design will detect the Failure Mode or its subsequent Failure Effect (detected by customer during installation)	8
Very Low	There is a very low chance the Design will detect the Failure Mode or its subsequent Failure Effect (detected by on-site customer quality)	7
Low	There is a Low probability the Design will detect the Failure Mode or its subsequent Failure Effect (detected at final inspection)	6
Moderate	There is a Moderate probability the Design will detect the Failure Mode or its subsequent Failure Effect (detected during the subsequent stages or quality inspections)	5
Moderately High	There is a Moderately High probability the Design will Detect the Failure Mode or its subsequent Failure Effect	4

	(detected during stage quality inspection)	
High	There is a High probability the Design will detect the Failure Mode or its subsequent Failure Effect (detected at the next centre)	3
Very High	There is a Very High probability the Design will detect and/or anticipate the Failure Mode or its subsequent Failure Effect (detected before movement to the next centre)	2
Almost Certain	There is an almost certain probability the Design will detect and/or anticipate the Failure Mode or its subsequent Failure Effect (detected at the same centre)	1

Criticality

Table 0.3: Criticality Table

Effect	Automobile Industry Ranking	Criteria: Severity of Effect
Hazardous (without warning)	10	Very high severity ranking when a potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulations without warning.
Hazardous (with warning)	9	Very high severity ranking when a potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulation with warning.
Very High	8	Vehicle/item inoperable, with loss of primary function.
High	7	Vehicle/item operable, but at reduced level of performance. Customer dissatisfied.
Moderate	6	Vehicle/item operable, but comfort/convenience item(s) inoperable. Customer experiences discomfort.
Low	5	Vehicle/item operable, but comfort/convenience item(s) operable at reduced level of performance. Customer experiences some dissatisfaction.
Very Low	4	Cosmetic defect in finish, fit & finish/squeak & rattle item that does not conform to specifications. Defect noticed by most customers.
Minor	3	Cosmetic defect in finish, fit & finish/squeak or rattle item that does not conform to specifications. Defect noticed by average customer.
Very Minor	2	Cosmetic defect in finish, fit & finish/squeak or rattle item that does not conform to specifications. Defect noticed by discriminating customer.
None	1	No effect.

(SAE ARP5580)

3.3. Weighted RPN

Weighting is the process of assigning priorities to a data set to reflect real world results. In the PFMEA analysis percentage weighting is assigned to all the potential modes of failure to result in a single Risk value per work-centre. The weights are reassigned in the case of a change in RPN value resulting from a process change or a change in weights based on the engineers input for that work-centre based on continuing experience. Weights are also assigned to specific parts that have had multiple failures to indicate a critical part in the system and vice-versa.

3.4. Process Repeatability

Process repeatability is the ability to repeat a process given the same conditions. Process repeatability is achieved by a combination of process manuals, employee training and an efficient and complete reporting system. Process repeatability is a key factor in taking a project from development stages to regular production. Achievement of process

repeatability ensures quick handover to production and the achievement of customer delivery objectives

4. METHODOLOGY

4.1. PFMEA and Input Matrix

To identify the issues that were causing the delays in the production process, it was decided to conduct PFMEA analysis at all the work-centres in the project. Training was provided to the engineers who were involved in the project; due to irregularities noticed in the initial runs of PFMEA analysis. A successful completion of PFMEA analysis covering all the work-centres were conducted over a 3-week period with direct consultation with the trained engineers. Ratings were assigned with respect to Occurrence(O), Detection (D) and Criticality (C).

Due to the nature of the products being manufactured it was decided by consultation with the engineers and the Dy. Manager that the maximum criticality of the parts would be 6. This was done due to the nature of the assemblies and the criticality to flight operations as is indicated by the criticality table.

i.e. For Work-centre A

$RPN_i = C_i * O_i * D_i$ where i = the specific failure (1)

To assign a single Risk Number to each work-centre, percentage weighting was performed on the individual failure RPN values. This gives the sum of the percentage weighted RPN values. Percentage weighted average automatically assigned a higher weightage for more critical operations. This form of weightage was considered because it does not slow down the process of weighting of errors and is dynamic with the change in RPN for a work station after changes to improve the operations at the work-centre are carried out.

The RPN of the work-centre RPN_j is calculated by

$RPN_j = \Sigma\ (RPN_i^2 / \Sigma\ RPN_i)$ where j = work-centre (2)

Further it was noticed that while most parts did not suffer failures at the bending process some parts suffered from repeated failures at the work-centre. It was decided to assign an additional weightage to parts that have been rejected from the system. This weightage is assigned to parts to reflect the higher criticality of those particular parts with a history of failure. This weightage has been considered taking into consideration the type of failure and changes as it is updated as per regular production of parts and the NC data.

The following data is input into a matrix with the work centres as the columns and the panels, sub-assemblies and assemblies as the rows. the matrix is created by comparing the SAP routing sheets of each panel, sub-assembly and assembly. The resulting matrix gives an overview of what operations are carried out for each assembly.

The final weighted RPN values for each work centre are input into the input matrix structure. The sum of the RPN values of the operations pertinent to a panel or assembly gives the risk factor for the manufacture of the panel or assembly.

Risk of Panel or Assembly, $R_a = \Sigma RPN_j$ where a is the Panel or Assembly Number (3)

The RCA scrap data for the same is also input into the same structure. A specific weightage (W_k) is assigned to every panel which has been scrapped from the process based on the type of failure and the occurrence of the same. This additional weightage is assigned to the work-centre at which the failure has occurred. This is done to account for the increasing criticality of specific parts that have suffered multiple failures.

$0 < W_k < 1$ where W_k is the weightage assigned to the part based on the RCA data

Final Risk of Panel or Assembly, FRa = Ra + Wk* RPNj (4)

4.2. Creation of SFG stock

It was observed that on the rejection of apart from the system, the re-issuance of a part would result in a fresh part going through layup and machining and then finally arriving at the work-centre where the failure had occurred previously. This resulted in a very long lead time of over a week for the completion of the critical operations that tend to have a high failure rate. Due to this, it was decided to create a step in the process such that SFGs could be generated in the system and stored separately, for direct consumption to be converted into FGs.

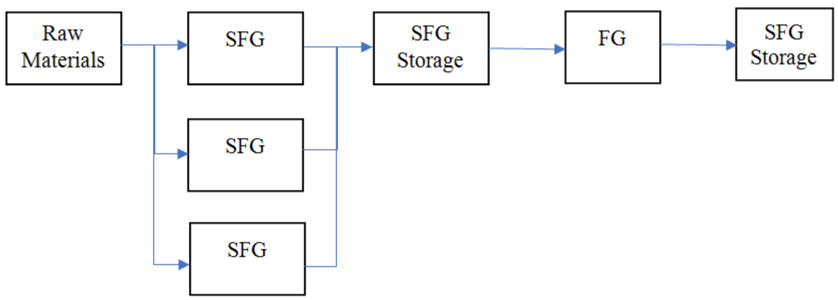

Figure 0.1: SFG Storage Process Flow

The operations until the completion of demoulding were identified as non-critical operations. Therefore, on the completion of the demoulding stage, the parts are moved to SFG storage. For the further operations the required parts are taken from the SFG and all the subsequent operations are carried out. In due course of time the machining operation was deemed a non-critical operation and the SFG parts were machined post demoulding.

4.3. Identification of Critical Operations

From the initial PFMEA analysis, it was found that bending operation was of high criticality, with the RPN value of some failures exceeding 90. During production of parts it was noticed that multiple parts were failing due to cracks forming at the bend radius. This prompted the engineers to conduct trials on a sample with varying slot thicknesses, varying slot height. The resultant of that was the reduction in the number of failures due to cracks in parts. These tests also identified a flaw in the drawings provided by the customer, multiple trials resulted in cracks forming when parts were bent beyond a radius tolerance of 55mils, while the drawing called for a tolerance of 50mils. This sparked a conversation with the customers to provide a relaxation of 10mils in those parts. The discussions are still ongoing.

Similarly, at the layup stage, parts were getting rejected due to misplaced core and foam locations. The issue has been fixed tentatively with the provision of detailed drawings of the location of the core and foam in the route cards. Templates were made for all parts for the layup stages to permanently prevent rejections resulting from the misplacement of foam and core or the placement of cores in the wrong directions

A proper method of nesting of the layup process was not carried out. This resulted in a mere 30% nesting efficiency. This resulted in extremely prolonged periods for all the parts to get cured in the autoclave. It was decided to re-nest all the parts in the project. This resulted in the nesting efficiency going up from 30% to 74%. It was also identified that the parts did not have to be cured in the autoclave, it was thus decided to make a switch to curing the project parts in an

oven. This led to the number of parts cured per week to go up from 48 to 58 parts on an average. Due to availability constraints in the plant for the oven, a new oven was purchased and installed during the manufacturing of the 4th shipset. This oven was larger than the old oven and further increased the number of parts cured per week to 82.

The declam operation was being conducted for the first time in the factory. This resulted in a lack of skilled operators who were familiar with the job at hand. This led to multiple failures and delays due to rework operations having to be conducted multiple times during the manufacturing of a parts. Thus, training was provided to the operators, and fresh operators were hired and trained to cover up for the extreme delays resulting from the declam operation. The training was a success, but after 3 months of progress multiple operators who handled multiple operations including declam quit. It was then decided to hire a team of operators only to perform the critical delcam operation and training only for declam was provided for the newly recruited operators.

Similarly, errors were identified and corrected following the PFMEA analysis.

5. RESULTS ANALYSIS

From the PFMEA analysis the layup and bagging, machining, bending, declam application, and extrusion bonding were identified as critical work-centres.

- Templates were created for the all the parts; these templates were later on replaced by the Laser projection system. These templates prevented the parts from being layed up in the wrong orientation, they also prevented the misplacement of the foam blocks.
- Hot-air guns were used during the declam operation, this helped in wrapping the declam around contours and also prevented warping.
- Bending fixtures were modified to better constrain the parts and poka-yoke techniques were introduced in the fixtures to further reduce rejections.
- Bending trials were conducted for varying slot lengths, slot thicknesses and slot depths, the dimensions of which were taken as per the part drawings. This helped to identify which parts would be critical due to tight tolerances.
- Templated for the extrusions were created and special templates for mitre cuts were created.
- The nesting of parts was done with a focus on nesting efficiency rather than the order of parts required to complete the assemblies. The machining nesting used the same template as the layup nesting. This resulted in a 40% increase in the nesting efficiency and thus drastically improved the productivity.
- It was identified that certain small parts of a common thickness and layer height were layed up together and then machined to yield the individual parts. This clubbing was done only based on thickness and layer height. Some of the clubbed parts were required in multiple numbers for a single shipset, while other parts were not required in multiple numbers. This caused multiples of some parts being stocked for no reason. The clubbing was redone, and those parts were split from the clubbing.
- There were multiple cases of mislabelling of machining programmes in the process sheets for the parts. These were rectified to prevent the errors.

- A new process for insert potting was created to prevent depressions from forming during the installation of parts on the threaded inserts.
- A special team only to perform declam application was constituted, this helped in concentration of talent, it also reduced the time taken for training of operators from 3 months to 3 weeks.
- Nesting was performed for cores and foam blocks, the cut core and machined foam pieces were packaged and stored together on a per part basis. This helped in reducing errors resulting from wrong raw material movement.

The creation of the SFG stock helped to speed up the production process by reducing the waiting time for parts that have a high recorded rate of failure. The high criticality parts were obtained from the input matrix being the parts with the highest number of failures and subsequently an elevated risk associated with the parts. While special focus was assigned to the clearance of critical parts, a buffer of critical parts was always maintained in the case of the failure of the part especially during the stages of bending or declam application. Initially the SFG stock was maintained after the demoulding of the cured parts. The creation of templates and the use of edge bars reduced the number of failures from the layup work-centre. On completion of the required repairs to the Flexicam machine and its subsequent proving of machining the parts without the previously noticed error, the SFG storage of parts was performed after the completion of machining operation.

From the correlation analysis by Karl Pearson's Correlation shows that there is a significant correlation between the Scrap data and the Panel and Assembly risk data created using the PFMEA analysis. The Correlation factor will continue to increase as the data set evolves with data input from regular production as well as continuous improvement processes

Correlations

Table 0.1: Panel Correlation

		Panel RPN	Scrap
Panel RPN	Pearson Correlation	1	.382**
	Sig. (1-tailed)		.000
	N	136	136
Scrap	Pearson Correlation	.382**	1
	Sig. (1-tailed)	.000	
	N	136	136

**. Correlation is significant at the 0.01 level (1-tailed).
Panel RPN – Final Panel Risk Score
Scrap –number of scrapped panel parts

Correlations

Table 0.2: Assembly Correlation

		ARPN	ASCRP
ARPN	Pearson Correlation	1	.222**
	Sig. (2-tailed)		.010
	N	136	136
ASCRP	Pearson Correlation	.222**	1
	Sig. (2-tailed)	.010	
	N	136	136

**. Correlation is significant at the 0.01 level (2-tailed).
ARPN –Final Assembly Risk Score
ASCRP – Number of scrapped assembly parts

The Input matrix gives the Risk involved in the manufacturing of the Panels and Assemblies. It indicates the work centres at which failures tend to occur at and the operations performed that caused the failure. It also indicates the specific parts that have a higher risk of manufacturing than other parts and special interest can be given to these parts.

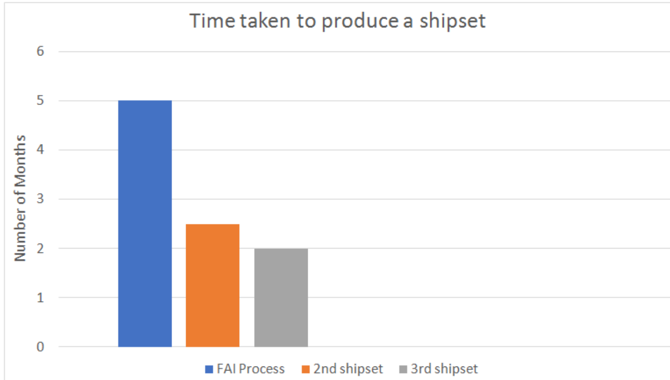

Figure 0.1: Time Taken to Produce a Shipset

The above graph shows the number of shipsets manufactured vs time. This clearly shows the positive impact of the PFMEA analysis on the project. The stages of machinery change for curing operations after the 2nd and 4th shipsets are clearly visible. The graph post PFMEA analysis also indicates the sudden and rapid increase in the rate of manufacturing achieved by improving the nesting efficiency coupled with the machinery changes. The machinery changes were included in the results without the PFMEA analysis because such decisions on high capital expenditure were taking at the time of the securing of the order from the customer and the PFMEA analysis had no role to play in that decision making.

Table 0.3: Effect of Resource Dilution on 9th Shipset

Time (Week)	Original	After Conducting PFMEA	70% Resource Dilution	60% Resource Dilution	50% Resource Dilution	40% Resource Dilution	30% Resource Dilution
50	4	7	7	7	7	7	7
51	4	7	7	7	7	7	7
52	4	7	7	7	7	7	7
53	4	8	8	8	8	8	8
54	4	8	8	8	8	8	8
55	5	8	8	8	8	8	8
56	5	9	9	9	9	9	9
57	5	9	9	9	9	9	9
58	5	9	9	9	9	9	9
59	5	10	9	9	10	10	10
60	5	10	10	10	10	10	10
61	6	10	10	10	10	10	10
62	6	11	10	11	11	11	11
63	6	11	11	11	11	11	11
64	6	12	11	11	11	11	11
65	6	12	12	12	12	12	12
66	6	12	12	12	12	12	12

The above table shows the number of shipsets manufactured and the effect of the resource dilution on the same after week 55. As is evident from the graph, there is no appreciable change in the time taken to manufacture a shipset for a resource dilution between 30 and 50%. This is not the case for resource dilution of 60% and 70%, in these cases the 9th shipset of the project takes 4 weeks rather than the customer required 3 weeks. This will result in a backlog which in not

acceptable at such a mature stage in the production process. The table also indicates how the production capacity of the project almost doubles after the PFMEA is completed and the correction of faults in the system are rectified and the nesting efficiency is improved.

6. CONCLUSIONS

The PFMEA conducted on the work-centres of the project with an added focus on reduction of delays and the increase of rate of production formed a sound basis upon which the individual parts being processed could be risk analysed. This was realised by means of a matrix of the parts and their assemblies and, the work-centres, to yield the risk associated with the manufacturing of the individual parts in a shipset. The work-centres' were assigned a weightage by percentage weighting of the individual identified failures. The risks assigned to the work centres were summed up on an individual part, sub-assembly or assembly basis. This resulted is the risk involved in manufacturing the parts, sub-assemblies and assemblies. Additional risks were added to certain parts that showed a pattern of multiple failures, this helped in identifying a pattern in failures in specific work-centres, this resulted the correction of some failures and identification of others by means of trials being conducted on the operation at that work-centre. The additional focus on the increase in processing efficiency, increase in production rate and reduction in delays resulted in the creation of quick solutions that resulted in the realisation of the target of achieving the customer required delivery schedule of one shipset every three weeks. The first stage of production before being moved to semi-finished goods storage was considered and studied under the lens of system dynamics, the model includes an inclusion of the PFMEA process to better understand the factors affecting the analysis method as well as its effect on the production system. The results showed that for a planned resource dilution after 55 weeks of production to another project, the project could support up to a 50% resource dilution and achieve the customer required deadline 3 shipsets per week. A resource dilution of more than 50% results in a shipset being manufactured every four weeks.

REFERENCES

1. *ARP5580, S. A. E. (2001). Recommended Failure Modes and Effects Analysis (FMEA) Practices for Non-Automobile Applications. Warrendale: Society of Automotive Engineers.*
2. *AS9100-D, S. A. E. (2016). Quality Management Systems—Requirements for Aviation. Space and Defence Organizations.*
3. *Bahrami, M., Bazzaz, D. H., & Sajjadi, S. M. (2012). Innovation and improvements in project implementation and management; using FMEA technique. Procedia-Social and Behavioral Sciences, 41, 418-425.*
4. *Baker, M. D. D., Mooney, M. D. P., Center, D., & Airplanes, B. C. (2014). BOEING 787–8 DESIGN, CERTIFICATION, AND MANUFACTURING SYSTEMS REVIEW.*
5. *Eizakshiri, F., Chan, P. W., & Emsley, M. W. (2015). Where is intentionality in studying project delays?. International Journal of Managing Projects in Business, 8(2), 349-367.*
6. *Estorilio, C., & Posso, R. K. (2010). The reduction of irregularities in the use of "process FMEA". International Journal of Quality & Reliability Management, 27(6), 721-733.*
7. *Failure Modes and Effects Analysis (FMEA), Critical Items List (CIL), and Fault Tree Analysis (FTA) Gary G. Kelm., Chief Program and Project Assurance Division NASA - Glenn Research Center Cleveland, https://prod.nais.nasa.gov/eps/eps_data/161793-AMEND-002-002.pdf Retrieved on 15/07/2018*

8. Greasley, A. (2005). Using system dynamics in a discrete-event simulation study of a manufacturing plant. International Journal of Operations & Production Management, 25(6), 534-548.

9. Hwang, L., & Hu, G. (1999). Steps in conceptualizing a system for system dynamics model-building: a case study of an oil refinery of a petroleum corporation. In Proceedings of the 1999 International System Dynamics Conference.

10. Jodkowski, L. (2015). Possibilities and Methods of Risk Assessment under ISO 9001: 2015. International Journal of Managerial Studies and Research (IJMSR), 3(10), 14-23.

11. Lipol, L. S., & Haq, J. (2011). Risk analysis method: FMEA/FMECA in the organizations. International Journal of Basic & Applied Sciences, 11(5), 74-82.

12. Logasakthi, K., & Rajagopal, K. (2013). A study on employee health, safety and welfare Measures of chemical industry in the view of Salem region. Management (IJRBM), 1(1), 1-10.

13. Lyneis, J. M., & Ford, D. N. (2007). System dynamics applied to project management: a survey, assessment, and directions for future research. System Dynamics Review: The Journal of the System Dynamics Society, 23(2□3), 157-189.

14. MP, J., & PK, M. Prospects of cattle feed industry in India and strategies for utilizing the market potential: A study in Kerala with a focus on factors influencing buyer behaviour.

15. Paciarotti, C., Mazzuto, G., & D'Ettorre, D. (2014). A revised FMEA application to the quality control management. International Journal of Quality & Reliability Management, 31(7), 788-810.

16. Ramana, T. V, & Varaprabhakar, P. Impact of work stress on employee satisfaction of confectionery industry in Andhra Pradesh.

17. Reliability Analysis Centre, Failure Mode, Effects and Criticality Analysis (FMECA)

18. Robinson, C. B. (1990). Auditing a quality system for the defense industry. ASQC Quality Press.

19. SAE, AS. 9102. First Article Inspection Requirements.

20. Singh, J., & Singh, HAERO (2015). Continuous improvement philosophy–literature review and directions. Benchmarking: An International Journal, 22(1), 75-119.

21. Varaprabhakar, P., & Ramana, T. V. Impact of work stress on employee satisfaction of confectionery industry in Andhra Pradesh.

22. Steimer, C., & Aurich, J. C. (2016). Analysis of information interdependencies between product development and manufacturing system planning in early design phases. Procedia CIRP, 50, 460-465.

23. Waghmare, S. N., Raut, D. N., Mahajan, S. K., & Bhamare, S. S. (2014). Failure mode effect analysis and total productive maintenance: A review. International Journal of Innovative Research in Advanced Engineering (IJIRAE), 1(6), 183-203.